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DIVISION - THE AVIATION CORPORATION WILLIAMSPORT, 38, PENNA.

MULTI-REED VALVE COMBUSTION CHAMBER
ANALYSIS OF TEST DATA OF REPORT NO. 1097

DOWNGRADED UNCLASSIFIED

UNCLASSIFIED

REPORT NO.

1121

Date of Report:

FORM 674 13M 4 46

May 26, 1947

RESTRICTED

MULTI-REED VALVE COMBUSTION CHANGER AMALYSIS OF TEST DATA OF REPORT NO. 1097

Reported by:

Project Engineer

Approved by:

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✓Bureau of Aeronautics (5) Experimental File (2)

Engineering Records

RESTRICTED

REPORT NO. 1121

MULTI-REED VALVE COMBUSTION CHAMBER ANALYSIS OF TEST DATA OF REPORT NO. 1097

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REPORT NO.

MULTI-REED VALVE COMBUSTION CHAMBER ANALYSIS OF TEST DATA OF REPORT NO. 1097

OBJECT:

FORM 874 (9H 4-49

1. The object of this report is to present the results of an analysis of the data in Lycoming report No. 1097, "Initial Test of the Multi-Reed Valve Combustion Chamber, Section I, Item 3, Contract NOm(s)-4718".

SUMMARY:

- 2. The initial tests of the reed valve combustion chamber show a marked improvement over the rotary sleeve valve chamber previously tested. (Lycoming reports No. 1056 and 1073.)
- 3. Calculated mean chamber pressures up to 142% of the supply air pressure were obtained with a combustion efficiency of 48%.
- 4. The maximum combustion efficiency obtained was 59%. This figure has been improved during subsequent tests.
- 5. This chamber has not been made to function consistently at air supply pressures much above 25 pei gage.

DESCRIPTION:

- 6. The multi-reed combustion chamber, drawing No. 70727, which is the subject of these tests is fully described and pictured in report No. 1097.
- 7. The interior of the chamber is 5 inches in dismeter and 22 inches long resulting in a volume of .25 cubic foet. Eighteen flat reeds of carbon steel are used in a cylindrical array. Each reed is .031 x .56 x 4.69 inches. The throat of the exhaust nossle used for these tests is 1.06 inches in diameter. Ignition was by continuous spark from "Ford" vibrator coils. The fuel was 73 octane aviation gasoline. Timing of the cycles was accomplished by the fuel injections.

METHOD OF TEST:

FORM 674, 14H 4-46

- 8. These variables were regulated. Supply air pressure, cyclic speed, and rate of fuel supplied.
 - 9. The supply air temperature was not controlled.
- 10. In addition to the observed values of the above, data were taken for the determination of thrust, heat rejection to the cooling water, and air consumption.
- 11. A number of cards were taken with an MIT balanced diaphragm indicator and a few photographs of oscilloscope traces from a "Trimount" pressure pick-up were obtained.
- 12. For the purpose of this report a selection of data was made from report No. 1097. This served to reduce the runs to a convenient number and to discard obviously poor results. The basis of selection was to retain those runs having the highest ratio of thrust to mass air flow for equivalent supply air pressures, fuel air ratios and cyclic speeds. In general, all of the runs of any closely related series were retained as a unit.
- 13. Mean chamber pressure and apparent combustion efficiency are taken as the criteria of performance. These are calculated from the conserved mean thrusts and fuel and air consumptions in accordance with the method outlined in Appendix A of report No. 1073.
 - 14. The mean chamber pressure is taken as

$$P_{\rm m} = .797 \frac{E}{d} + 11.55$$

there Pm

= mean chamber pressure - psi abs.

Fi = observed mean jet thrust - lb.

q = area exhaust nozzle throat - sq. in.

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15. The apparent combustion efficiency -

$$\eta_{c} = \frac{(i+m)h_{z} - mh_{i} + \frac{Jacket\ Loss}{W_{F}}}{CE\ FUEL}$$

where

m = air/fuel ratio

hg = enthalpy of products of combustion taken as air at T₂ - btu/lb.

h = enthalpy of supply air -btu /lb.

CE FUEL = chemical energy of fuel = 19,000 btw/lb.

W_f = fuel consumed - 1b/hr

Jacket Loss - as observed - btw/hr.

$$T_2 = \left(1860 \, a \, \frac{P_m}{Wa} \cdot \frac{m}{m+1}\right)^2$$

 $W_a = air consumed - 1b/hr.$

The enthalpies h; and he are taken from a tabulation of air properties. The atmospheric pressure is assumed 14.5 psi.

RESULTS:

- 16. Plots of the calculated mean chamber pressures for 29.5, 34.5, and 39.5 supply air pressures are shown on curve sheets No. 7666, 7667, and 7668, pages, 9, 10, and 11. The curves are drawn for the best operation (highest mean pressures) without regard for cyclic speed. The curves are reproduced for comparison on curve sheet No. 7669, page 12.
- 17. The optimum cyclic speed is about 1,000 per minute with tendency to increase slightly with increasing fuel flows.
- 18. There is an upper limit to the amount of fuel which may be supplied at any given air pressure and cyclic speed and still maintain normal operation.

 An increase of fuel beyond this critical rate suppresses the violence of the cyclic explosions and results in a "torching" approximating constant pressure combustion. Curve sheet No. 7666, page 9, shows points for 900 and 1,000 cycles

per minute that are definitely in this "torching" condition. The cause is possibly a puddling of excess fuel in the chamber bottom.

- 19. Calculated combustion efficiencies are shown for the several supply air pressures on curve sheets No. 7670, 7671, and 7672, pages 13, 14, and 15. The curves are reproduced for comparison on curve sheet No. 7673, page 16. As a matter of general interest these efficiencies have been plotted against air-fuel ratios instead of fuel consumption on curve sheets No. 7674, 7675, and 7676, pages 17, 18, and 19.
- 20. Measured air flow versus fuel flow for the three supply pressures are shown on curve sheets No. 7677, 7678, 7679, pages 20, 21, and 22. The curves are reproduced for comparison on curve sheet No. 7680, page 23. The inordinately high air flows shown for 900 cycles on curve 7679, page 22, appear to be associated with some malfiring or malfunctioning possibly of the fuel injection pumps. Subsequent runs have shown air flows under these same conditions compatible with the curve as drawn.
- 21. The curves in all cases have been drawn as envelopes defining approximately the best performance recorded, that is, drawn through the points of maximum mean pressure, maximum combustion efficiency, and minimum air flow, excluding only such points that appear discordant. That these curves generally pass through or close to corresponding data points in each case justifies this procedure.

DISCUSSION:

FORM 874 10W-4-44

22. The results of these tests have been presented in the same fashion as those of the previous sleeve valve tests in report No. 1073. In this case the effects of the several variables can be separated and trends made evident.

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- 23. The improved action of this second chamber is evidenced not only by the higher chamber pressures obtained but also by the relatively consistent data resulting from the more regular functioning.
- 24. The irregularity of firing at supply air pressures much above 40 psi abs. was such that usable data could not be obtained. This limitation should be further investigated. It is probable that this limiting pressure will be increased by any measures resulting in better combustion.
- 25. The maximum combustion efficiency of 59% leaves considerable room for improvement. Subsequent experiments with certain modifications of the chamber have shown considerably higher efficiencies. It is also expected that the projected heating of the supply air will result in a marked improvement.
- 26. The present supply air temperature is seldom above 150° F. because the compressors are intercooled and the manifold system has a very large cooling area. In the actual use of a combustion chamber on an engine the air discharged by the rotary compressor would have a much higher temperature which should certainly improve the vaporization of the fuel.
- 27. There was a remarkable freedom from valve trouble during the course of these tests. Taken together with subsequent running it appears that at least one hundred hours may be expected from the present reeds. Since this is approximately 3,600,000 cycles it is possible that by slight development the reeds may be given a very long life.

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SELECTED DATA #70727 MULTI-REFD VALVE COMBUSTION CHAMBER

RUN	X	IR SÚPP	T.V	SPEED	FUEL	THRUST	TACKED TODA
No.	<u> </u>		r				JACKET LOSS
	PRESS. psi abs.	TEMP.	FLOW 1b/hr	СРМ	lb/hr	1b	btu/hr
543	29.5	580	1533	699	34.7	23.4	45,400
544 545	29.5 29.5	58 3 58 1	1507 1470	702 703	43.2 52.6	24.7 25.1	51,400 51,600
546	29.5	579	1440	705	55.3	24.8	55,000
55 7 5 58	29.5 2 9. 5	598 600	1517 1500	906 907	35.9 40.0	25.0 26.8	51,500
559	29.5	603	1460	908	54.5	28.4	53,500 64,100
560 561	29.5 29.5	603	1402	900	67.7	29.2	74,300
562	29.5	603 606	1380 1335	902 911	74.0 85.0	29.3 30.5	73,600 76,600
56 3	29.5	604	1017	899	91.5	22.3	74,000
564 565	29.5 29.5	602 606	148 8 1 448	997 998	43.4 51.6	27.25 28.7	61,500 60,000
566	29.5	606	1368	1002	62.7	29.3	63,400
567 568	29.5 29.5	602 60 3	1333 1323	1008 995	78.5 88.5	30.3 30.8	63,900 68,500
569	29.5	605	1250	1000	96.0	31.15	70,640
570	29.5	601	1008	998	99.5	22.9	63,500
571 572	29.5 29.5	601 5 99	1343 1322	1111 1100	53.4 64.4	28.1 29.6	63,500 69,300
5 73	29.5	595	1285	1102:	77.3	29.9	78,500
57 <u>4</u> 575	29.5 29.5	597 594	1263 1218	1106 1112	82.5 97.6	30.3 30.8	79,800 81,000
576	29.5	592	1200	1098	103.6	31.2	84,300
577	29.5	601	1147	1106	115.0	30.0	75,400
57 8 5 7 9	29.5 29.5	591 591	1350 1250	1206 1211	49.2 63.4	27.3 29.0	62,400 · 63,700
580	29.5	591	1238	1198	72.2	29.8	73, 500
58 1 582	29.5 29.5	590 590	1218 1163	1203 1212	83.2 102.4	30.1 29.6	74,900 77,700
583	29.5	589	1156	1200	115.0	29.6	78,400
584	29.5	588	1122	1205	131.3	28.7	69,200
3 80	34.5	586	1535	708	62.1	32.1	63,900
381	34.5 34.5	589	1470	708	64.7	31.1	64,600
382 407	34.5 34.5	591 560	1304 1830	713 703	103.5 36.8	30.0 30.6	61,600 56,200
408 409	34.5 34.5	568 572	1795	707	46.2	32.6	60,600
411	34.5	578	1760 1466	710 701	54.0 65.4	3 3. 6 31.6	62,000 63,900
412	34.5	582	1710	700	55.6	33.2	59,800

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REPORT NO. 1121

SELECTED DATA #70727 MULTI-REED VALVE COMBUSTION CHAMBER

			···				
RUN No.	A	IR SUPPI	ΥY	SPEED	FUEL	THRUST	JACKET LOSS
NO.	PRESS. psi abs.	TEMP.	FLOW 1b/hr	СРМ	lb/hr	1 b	btu/hr
678 679 680 681 673 674 675	34.5 34.5 34.5 34.5 34.5 34.5 34.5	523 541 548 552 565 565 566	1753 1710 1680 1670 1658 1632 1615	897 905 895 900 907 900 903	46.8 58.0 73.0 81.7 92.5 100.2	31.6 33.9 35.3 36.1 36.9 37.2 37.6	57,400 74,300 93,200 92,200 88,800 91,600 92,500
246 247 249 250 251 252 253 256	34.5 34.5 34.5 34.5 34.5 34.5 34.5	608 609 612 613 613 614 613 620	1717 1679 1612 1628 1566 1545 1513 1488	995 998 1006 1000 1007 1010 1015 995	56.7 74.0 85.5 74.9 93.1 99.1 108.0 112.0	35.6 36.6 38.2 36.3 38.7 40.0 40.0 38.6	77,800 85,600 92,100 92,800 92,600 95,100 93,400 90,800
257 258 259 260 261 262	34.5 34.5 34.5 34.5 34.5 34.5	619 619 617 616 615 615	1575 1518 1531 1511 1490 1486	1089 1114 1095 1095 1098 1102	65.6 82.5 86.2 91.4 100.8 107.0	35.8 38.0 40.0 38.9 39.0 39.2	84,200 90,400 94,100 97,200 97,200 97,500
263	34.5	614	1313	1232	127.7	37.3	86,100
276 277 278 279 280 281 282	39.5 39.5 39.5 39.5 39.5 39.5	607 614 622 628 629 631 632	2142 2090 2025 1940 1922 1955 1853	700 703 710 712 706 704 711	41.0 49.0 60.5 67.4 74.5 76.7 90.4	38.2 39.6 40.2 39.2 40.0 40.4	64,600 65,200 64,800 66,500 65,400 58,400 71,600
313 314 315 316 317 318	39.5 39.5 39.5 39.5 39.5 39.5	609 610 609 609 609 609	2290 2245 2220 2203 2175 2140	900 902 903 907 907 908	57.3 69.5 77.1 84.2 86.5 97.5	42.2 13.8 44.9 45.9 46.2 45.5	78,700 96,300 102,700 101,000 101,000 106,100
414 415 416 417	39.5 39.5 39.5 39.5	592 590 590 590	1922 1952 1892 1887	1000 1004 1008 1010	59.9 73.4 79.5 87.2	43.2 45.5 46.6 47.5	75,600 100,500 101,300 105,500

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REPORT NO. 1121

SELECTED DATA #70727 MULTI-REED VALVE COMBUSTION CHAMBER

RUN	A	IR SUPP	LY	SPEED	FUEL	. Thrust	JACKET LOSS
No.	PRESS. psi abs.	TEMP.	FLOW 1b/hr	CPM	lb/hr	1 b	b tu/hr
418	39.5	587	1868	1012	94.1	48.3	113,000
419	39.5	576	1820	1020	107.8	49.2	114,300
420	39.5	598	1812	1003	105.7	48.6	111,900
421	39.5	59 1	1817	1003	107.5	49.0	116,100
424	39.5	590	1755	1106	82.5	44.3	117,800
425	39.5	581	1792	1101	100.9	44.3	111,200
427	39.5	579	1763	1100	131.3	47.5	111,900
428	39.5	580	1698	1108	119.6	48.0	115,000
429	39.5	588	1738	1100	109.8	47.5	112,400

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B. K. ELLIOTT COMPANY PITTSBURGH CLEVELAND

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